BOOKS RECEIVED

THE AMERICAN ILLUSTRATED MEDICAL DICTIONARY (DORLAND), New (11th) Edition, Revised and Enlarged, 1921. First published in 1900. A complete dictionary of terms used in medicine, surgery, dentistry, pharmacy, chemistry, veterinary science, nursing, biology, and kindred branches; with new and elaborate tables. Eleventh edition, revised and enlarged. Edited by W. A. Newman Dorland, M.D. Large octavo of 1229 pages with 338 illustrations, 141 in colors. Containing over 1500 new terms. Philadelphia and London: W. B. Saunders Company, 1921. Flexible Leather, $7.00 net; thumb index, $8.00 net.

This dictionary has been used constantly for many years by the research investigators of The Wistar Institute of Anatomy and Biology. For the last five years it has been the Publication Department authority for the preparation of manuscripts printed in the Journals and a valuable guide to correct capitalization (Acrel's ganglion, wolffian ducts, etc.) and the simplified usage of compounds.

The revisions have been so frequent that words coming into special and technical use were soon incorporated. The anatomical names of the Basle Nomina Anatomica terminology have the sign (B. N. A.) after them. The new terminology of the American Society of Bacteriologists is included, and the new bacterial names of this terminology are defined. Other features are: the pronunciation of words, many anatomic tables, chemical symbols and formulas, laboratory and clinical tests, reaction, staining and fixing methods.

The light weight paper, clear print, comparatively small size and round corners, durable and flexible binding, make this a very convenient book for constant reference.

THE ANATOMY OF THE HUMAN ORBIT AND ACCESSORY ORGANS OF VISION by S. Ernest Whitnall, Professor of Anatomy, McGill University, Montreal, Canada. Illustrated, 428 pages, index. London: The Oxford Medical Publications, Henry Frowde and Hodder & Stoughton, 1921. $12.00. The subject-matter of this work originally formed the substance of a series of lectures given to candidates for the Oxford Diploma of Opthalmology, and is here presented in an amplified and completed form.

THE BLOOD SUPPLY TO THE HEART in its anatomical and clinical aspects, by Louis Gross, M.D., C.M., with an Introduction by Horst Oertel, Strathcona Professor of Pathology, McGill University, Montreal. 172 pages, illustrated. New York: Paul B. Hoeber, 1921. $5.00.

(*Continued on page 240*)

Resumen por el autor, R. A. Boyden

Una vejiga pancreática típica desarrollada a expensas de un páncreas accesorio.

En un gato adulto ha hallado el autor un tipo de vejiga pancreática que difiere de todos los casos conocidos hasta el presente por estar relacionada directamente con el duodeno, en vez de las ramas del conducto pancreático. Mientras que en el tipo ordinario se considera derivada de un lóbulo aberrante del pancreas ventral, este ejemplar sin duda alguna se ha desarrollado a expensas de un divertículo accesorio semejante a los descritos en los embriones de cerdo por Lewis y Thyng ('08).

Translation by José F. Nonidez
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AUTHOR'S ABSTRACT OF THIS PAPER ISSUED
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A TYPICAL PANCREATIC BLADDER DEVELOPED FROM AN ACCESSORY PANCREAS

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THREE FIGURES

Although the pancreatic bladder has been recorded at least fourteen times in the domestic cat,[1] it has never been ascribed to any other vertebrate. Even in the cat this anomaly is considered rare, since Johnson ('14) examined nearly four hundred specimens during a period of five or six years without finding an additional case. Miller, who found eight of the fourteen cases reported, suggests in extenuation of his good fortune that there exists a breed of cats in his locality among which pancreatic bladders are of relatively frequent occurrence.

An explanation of this anomaly was early provided through the discovery of two specimens which, although devoid of pancreatic bladders, exhibited accessory lobes of pancreatic tissue in the vicinity of the gall bladder (Miller, '04). In one case this band of pancreas arose from the duodenal division of the main pancreatic duct and extended along the bile duct as far forward as the gall bladder. In the other case there was a small truncated pancreatic mass in the fossa vesicae felleae which communicated with the duodenal division by means of a duct unaccompanied by glandular tissue. These findings were duplicated and extended by Heuer in 1906. Still later Miller ('10) found another specimen combining the two features, namely, a distal pancreatic bladder drained by a duct, the proximal half of which was embedded in a projecting lobe of pancreas. From an analysis of these specimens he concluded that the pancreatic bladder of the adult represents a persistence of the left

[1] See review of literature concluding this paper.

ventral pancreas, which undergoes an aberrant elongation in the direction of the gall bladder. According to this hypothesis, the terminal portion of the lobe becomes dilated, forming the bladder, and the proximal portion atrophies, leaving only a duct. Strong support for this explanation has been offered by Lewis ('11), who described the left lobe of the pancreas, in two pig embryos, as traveling across the ventral mesentery in the direction of the liver, instead of either disappearing, as is normal, or growing around the duodenum to form an infrequent anomaly—the annular pancreas.

The pancreatic bladder discussed in this paper is the second found by the author during the last year. The first of these, in one of twenty-five cats prepared for a class in comparative anatomy, agrees essentially with other cases previously reported. In every instance the aberrant duct arises either directly from the undivided portion of the ductus pancreaticus, or, in close proximity to it, from one of its primary divisions. The second case, found in one of a group of twelve class specimens, is radically different from any other hitherto described. As seen in figure 1, the duct of the pancreatic bladder empties directly into the duodenum some distance below the orifice of the duct of Santorini (*acc.d.*), and it has no relation to the ducts of either the dorsal or ventral pancreas. Throughout its course it is freely patent, and it opens into the duodenum through an orifice which is readily demonstrable, since it is not subdivided by folds such as occur in the cat at the ampulla of the main duct. In the proximal half of its course it is enveloped in a long, slender lobe of pancreatic tissue (fig. 1, *acc.pan.*) which it drains. This lobe is covered by the same peritoneal investment as the head of the pancreas, but is otherwise independent of the main gland from which it projects. As the duct emerges from the lobe, at its duodenal end, it is exposed for a few millimeters, but as soon as it reaches the wall of the intestine it is again enveloped, this time in a layer of fat, which probably represents a part of the original lobe which has here undergone fatty degeneration. In its distal half the duct is free from enveloping tissue. The bladder into which it leads is embedded in the right median lobe of the liver.

It lies to the left of the gall bladder, in which respect it apparently agrees with eight and differs from six of the cases reported. The terminal portions of the two bladders are separated from each other by a lobe of hepatic tissue, but lower down the two bladders are covered by a common fibrous capsule. Both bladders are supplied by branches of the cystic artery, the main trunk of which traverses an isthmus separating the pancreatic bladder into distal and proximal divisions.

In other respects the pancreas is normal; its dorsal and ventral portions are united by a bridge of tissue which completes the ring around the portal vein. According to Heuer, this bridge had formed in about 71 per cent of the cats he examined. The duct of Santorini (fig. 1, *acc.d.*) was present in this specimen and was studied histologically. During its passage through the wall of the duodenum it was found to give off short diverticula—a characteristic which it has in common with the corresponding region of the accessory duct in man. The lobe of tissue (fig. 1, *acc.pan.*) enveloping the duct of the pancreatic bladder was likewise sectioned, and was found to consist of typical pancreatic tissue, but, in the part examined, devoid of islands. It was supplied with branches of the superior and inferior pancreaticoduodenal vessels which penetrated the head of the pancreas to reach the under surface of this lobe.

Interest in this case lies chiefly in the light which it throws upon the origin of pancreatic bladders in general. Two possible modes of development have previously been advocated, the first of which has been discussed at the beginning of this paper. According to this view, a lobe of pancreas having a central duct and abortive alveoli, pushes its way out beneath the bile duct and forms a terminal cyst in close relation with the gall bladder. An alternative origin, suggested by F. T. Lewis, is through the subdivision of the hepatic diverticulum. So regarded, pancreatic bladders are extreme instances of double gall bladder (for which Miller in 1910 said that they might be mistaken), emptying into a subdivided cystic and common bile duct. "The inferior subdivision (pancreatic bladder) has lost its connection with the liver, but has retained its connection with the ventral

pancreas'' (Lewis, quoted by Dresbach, '11). In support of this, the frequency of double gall bladders in the cat has been cited. Miller once found such a condition in a brother of a cat with a pancreatic bladder, and in a rather limited number of

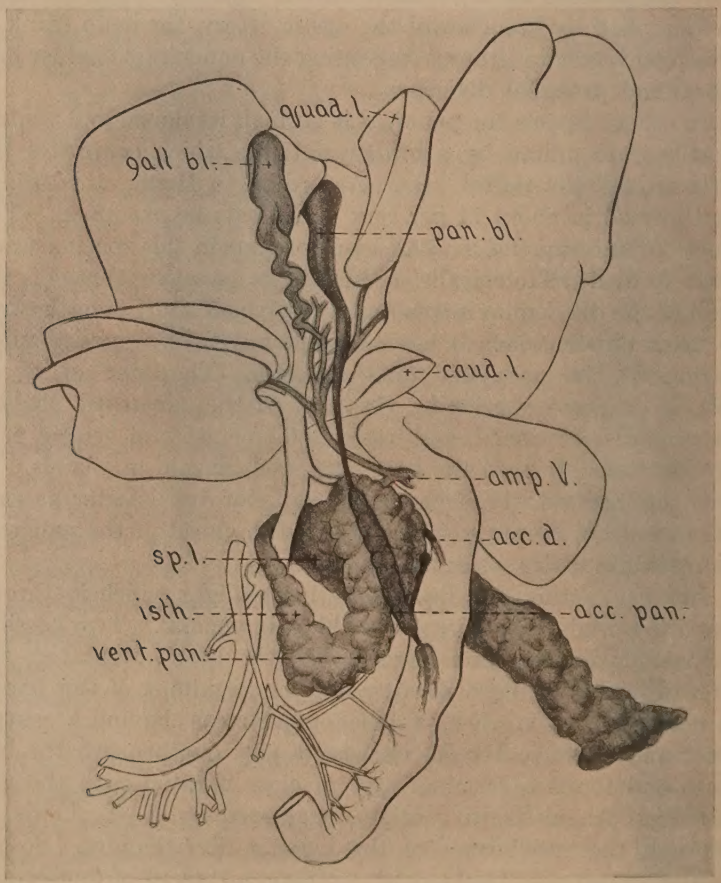

Fig. 1 Pancreatic bladder in a young female cat. *acc.d.*, accessory duct (Santorini); *acc.pan.*, accessory lobe of pancreatic tissue enveloping the duct of the pancreatic bladder; *amp.V.*, ampulla of Vater; *caud.l.*, caudate lobe of liver; *gall bl.*, gall bladder; *isth.*, isthmus connecting dorsal and ventral pancreases; *pan.bl.*, pancreatic bladder; *quad.l.*, quadrate lobe of liver; *sp.l.*, splenic lobe derived from dorsal pancreas; *vent.pan.*, ventral pancreas.

specimens examined a case was recently found by the writer. Notwithstanding certain difficulties which have caused this hypothesis to be discredited by Miller and Lewis, the similarity in structure of gall and pancreatic bladders and their close approximation render it attractive. There are certain cases to

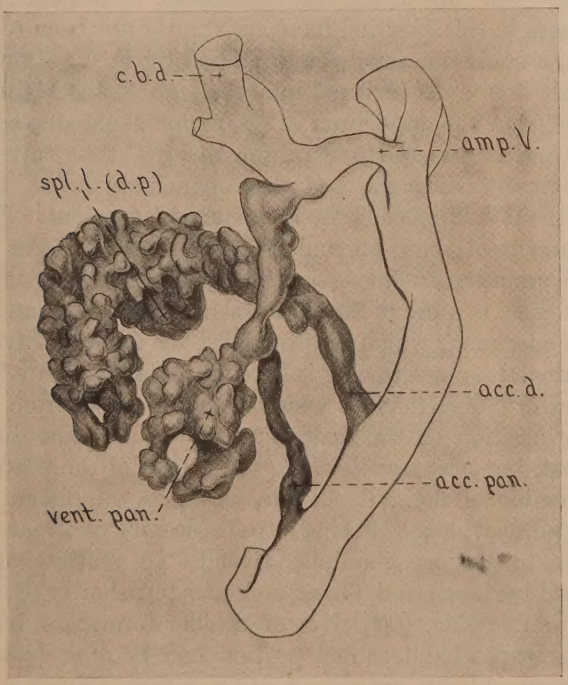

Fig. 2 Accessory pancreas in a pig embryo of 20 mm. × 55 diam. H. E. C., series 60 (model by F. W. Thyng). *amp.V.*, portion of the bile duct from which the ampulla of Vater is formed; *c.b.d.*, common bile duct. See figure 1 for other abbreviations.

which it may apply, notably the one recorded by Miss Beckwith; and Professor Bremer, at the recent meeting of the American Association of Anatomists, has given new interest to this interpretation by modifying it and correlating it with pancreatic development in the rat. But in other cases, and notably in

the one under discussion, the hypothesis of divided gall bladder can be definitely eliminated.

Since the pancreatic bladder in the present case empties into the intestine below the normal hepatic and pancreatic outgrowths, it must have arisen from an anomalous accessory pancreas well down on the duodenum. Although accessory pancreases in this position have apparently not been recorded in the cat, a short one has been described by F. C. Mann ('20) in the adult dog.[2] As pictured in figure 1 of Doctor Mann's paper, it arises from the duodenum in the region of the duodenojejunal flexure and is directed toward the pylorus, thus corresponding rather closely with the accessory pancreas under discussion, but without terminating in a cystic enlargement. The early development of these anomalous pancreases has been observed in a few embryos, the most suggestive of which, in relation to the present case, is a pig of 20 mm. described by Lewis and Thyng.[3] In this specimen, which was modeled by Doctor Thyng,[4] from whose model a new drawing is here presented as figure 2, there is an accessory diverticulum which not only arises from the same relative position on the duodenum as the aberrant duct in the adult cat, but also travels along the course of the portal vein in the direction of the gall bladder, as far as the dorsal pancreas. It thus gives evidence of being a true accessory pancreas, destined, perhaps, to produce glandular alveoli. In another pig embryo discussed by Lewis and Thyng a similar but shorter diverticulum has become cystic, suggestive of bladder formation, but in that case the expanded terminal portion had become detached and was presumably in process of degeneration. From a study of these pig embryos, it seems probable that the aberrant diverticulum of the cat (fig. 1) represents a corresponding structure which has undergone further development, and having reached the liver has there become expanded into a bladder. Although

[2] Accessory pancreas in the dog. Anat. Rec., vol. 19, p. 265, figs. 1 and 2.

[3] The regular occurrence of intestinal diverticula in embryos of the pig, rabbit and man. Anat. Rec., vol. 7, p. 508.

[4] Models of the pancreas in embryos of the pig, rabbit, cat and man. Am. Jour. Anat., vol. 7, p. 496.

originating as an accessory pancreas, from a primordium clearly distal in position to the normal pancreatic outgrowths, it has nevertheless duplicated the growth and transformation of the left lobe of the ventral pancreas in several of the cases of pancreatic bladder previously reported.

SUMMARY OF CASES

1815 MAYER, A. C. Arch. f. Anat. u. Phys., Bd. 1. Pancreatic bladder to right of gall bladder and smaller; duct terminates in trunk of ductus pancreaticus. This case was given considerable publicity. Cuvier (as noted by Lewis) described it in his Leçons d'anatomie comparée, 2e édit., vol. 4, part 2, p. 587, Paris, 1835; and Owen, as Doctor Shaner informs us, repeats the description, referring it to Cuvier, but not to Mayer, in his Anatomy of Vertebrates, vol. 3, p. 496, London, 1868. No additional case, however, seems to have been recorded during an interval of sixty-four years.

1879 GAGE, S. H. Amer. Quart. Mic. Journ., vol. 1, p. 123. Pancreatic bladder to right of gall bladder and larger; duct terminates at the junction of duodenal and gastrosplenic divisions of the ductus pancreaticus.

1904 MILLER, W. S. Am. Jour. Anat., vol. 3, p. 269. *Three cases:* pancreatic bladder to left of gall bladder and, in two cases, smaller; duct opens into duodenal division of the ductus pancreaticus, 6 or 7 mm. from its junction with the gastrosplenic division. *Two cases* of pancreatic lobes paralleling the course of the ductus choledochus.

1905 MILLER, W. S. Anat. Anz., Bd. 27, S. 119. Pancreatic bladder to left of gall bladder and "of nearly the same size;" duct terminates in gastrosplenic division as above.

1906 HEUER, G. C. Johns Hopkins Hospital Bull., vol. 27, p. 106. *Two cases* of pancreatic lobes paralleling the course of the ductus choledochus.

1910 MILLER, W. S. Anat. Rec., vol. 4, p. 15. Pancreatic bladder below, to right of gall bladder and (in the figure) of nearly the same size; duct accompanied by pancreatic tissue terminating in duodenal division.

1911 DRESBACH, M. Anat. Rec., vol. 5, p. 365. Pancreatic bladder below, to right of gall bladder and smaller; duct joins other divisions in forming common sinus before entering ampulla.

1914 JOHNSON, C. E. Anat. Rec., vol. 8, p. 267. Pancreatic bladder to left of gall bladder and smaller; duct terminates at junction of two divisions of ductus pancreaticus.

1920 LARSELL, O. Anat. Rec., vol. 18, p. 345. Pancreatic bladder on the left of gall bladder and slightly larger; its main duct empties into the duodenal division. *Three additional cases*, obtained by Professor Miller, are here briefly described. (Two of these had been recorded, without description, by Dresbach, '11.) One was similar in all respects to Miller's second case in 1904 (pancreatic bladder on the left and smaller, emptying into duodenal division of pancreatic duct); the second case "corresponded with the one reported in 1905;" the third was similar to Miller's case of 1910.

1920 Beckwith, Cora J. Anat. Rec., vol. 18, p. 363. Pancreatic bladder to right of gall bladder and smaller; macroscopically, no trace of pancreatic tissue in connection with the pancreatic bladder or its duct; this duct opens directly into the ductus pancreaticus only 5 mm. from the place where the latter enters the duodenum close beside the ductus choledochus; differs from all previous cases by having an anastomosis between the duct of the pancreatic bladder and the cystic duct; since the cystic duct is occluded beyond the anastomosis, which is a large one, the pancreatic bladder was apparently functioning as a gall bladder. (For the measurement (5 mm.) and for confirming the correctness of this résumé by comparison with the specimen, still preserved in the laboratory of Vassar College, the writer is much indebted to Professor Beckwith.)

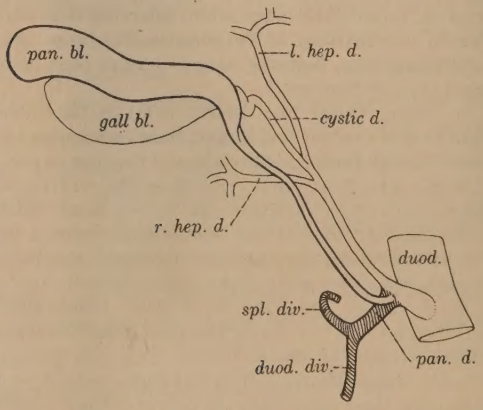

Fig. 3 Pancreatic bladder from a female cat. *duod.*, duodenum; *pan.bl.*, pancreatic bladder; *pan.d.*, pancreatic duct with splenic and duodenal divisions, *spl.div.* and *duod.div.*; *r.hep.d.*, *l.hep.d.*, right and left hepatic ducts; *cystic d.*, cystic duct; *gall bl.*, gall bladder.

The case reported by Miss Beckwith apparently belongs in the same class with the human double gall bladder recorded by Cruveilhier (Bull. de la soc. anat. de Paris, 1860, pp. 66, 67). The gall bladder which he described seemed to present merely a bifid fundus, but upon dissection it was found to be double as far as its neck. From the single neck two ducts were given off, one of which emptied into the hepatic duct. The termination of the other, very unfortunately, remains unknown, since it had been cut when the liver was removed at autopsy.

Even though the description is incomplete, it indicates that the specimen is essentially like Miss Beckwith's and that both should perhaps be removed from the group of pancreatic bladders. But if so, should not the following case, which is similar except that it lacks the anastomosis, be placed with them? It appears that the very different conditions of double gall bladder and true pancreatic bladder may be bridged in some instances by specimens which cannot be classified, since as yet a criterion for distinguishing them is not available.

1921 BOYDEN, EDWARD A. (the two cases reported in this paper):

Case 1. Pancreatic bladder to left of gall bladder and larger; its neck crosses that of the gall bladder, ventrally, to gain right side of bile duct; pancreatic bladder gray, empty, with walls thicker than those of the gall bladder; the walls of the two bladders fused throughout entire length and covered by a common fibrous capsule; cavities and ducts of two bladders not in communication with each other; duct of pancreatic bladder terminates in main stem of ductus pancreaticus, just before latter joins the common bile duct (fig. 3).

Case 2. Pancreatic bladder derived from accessory duodenal pancreas (for description, see text of this paper and fig. 1).

TOTAL NUMBER OF 'PANCREATIC BLADDERS' REPORTED

15 cases, derived either from an aberrant left lobe of the ventral pancreas or possibly from a subdivided gall bladder.

4 cases of an accessory lobe of pancreatic tissue paralleling the course of the ductus choledochus (which might be added to the above 15 as incomplete cases of pancreatic bladders).

1 case of pancreatic bladder derived unquestionably from an accessory duodenal pancreas.

Resumen por el autor, Shirley P. Miller.

Efectos de varios tipos de inanición sobre las mitocondrias del epitelio gastro-intestinal y pancreático de la rata albina.

La deficiencia en vitaminas y la inanición aguda pueden producir cambios en las mitocondrias de las células epiteliales gastro-intestinales y células glandulares del páncreas. La axfisia no produce aparentemente cambios tan marcados. La intensidad de la lesión sufrida por la célula debe ser muy grande para producir tales cambios. Cowdry ('20) ha llegado a las mismas conclusiones en sus experimentos sobre las raíces de las plantas.

Los cambios observados pueden consistir en: 1 (Una transformación de las mitocondrias bacilares en esféricas; 2) Una aparente reducción en el número de mitocondrias; 3) En la desaparición total de las mitocondrias de las células. A causa de la dificultad para obtener uniformidad en la técnica y las variaciones extremas observadas en las reacciones tintóreas, aún en las células normales, es evidente que debe observarse gran cuidado al derivar conclusiones con referencia a los efectos de los cambios del medio ambiente sobre las mitocondrias.

Translation by José F. Nonidez
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EFFECTS OF VARIOUS TYPES OF INANITION UPON THE MITOCHONDRIA IN THE GASTROINTESTINAL EPITHELIUM AND IN THE PANCREAS OF THE ALBINO RAT

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Although there is an extensive literature upon mitochondria, the most of this is of a purely morphological nature. But few investigations have been made to determine their modification in number, size, or shape under experimental or pathological conditions. The observations of Lewis' ('15) would indicate that mitochondria are very labile and variable in their morphology. Changes in mitochondria have been described by Homans ('15) in pancreatic islet cells during diabetes; by Scott ('16) in the pancreatic cells of white mice in phosphorus poisoning; by Goetsch ('16) in thyroid cells during goiter, and by Cowdry ('20) in plant rootlets subjected to various harmful conditions. McCann ('18) observed persistence of mitochondria in the nerve cells of monkeys dying of experimental poliomyelitis. Rasmussen ('19) was unable to find any appreciable decrease in the mitochondria in the nerve cells of hibernating woodchucks. Russo ('12) found an increase in the amount of mitochondria in the oöcytes of rabbits during lecithin feeding. Apparently the only published observations on the effects of inanition upon the mitochondria are the results briefly stated by Schun Ichi Ono ('20) at a meeting of the Anatomical and Anthropological Association of China. He demonstrated histological preparations showing the effect of starvation upon the mitochondria in the somatic cells of Ascaris, causing them to become granular. He also observed altered size and shape of mitochondria in the tissues of starved rodents. Since further investigation of this question seemed desirable, the present study was undertaken in

order to determine the changes in the mitochondria of the gastro-intestinal epithelium and of the pancreas in the albino rat during various types of inanition. During the progress of this study, it seemed wise to have for comparison some material which had been submitted to other experimental conditions than types of starvation. Therefore, a number of rats were asphyxiated by suffocation.

MATERIAL AND METHODS

The thirty-four albino rats used in these experiments were all males except three. The age of the animals ranged from new-born to adult. Three animals were new-born, weighing 4 grams each. Two were mature adults with a weight of about 275 grams. The remainder were young adults weighing from 140 to 160 grams. All animals were weighed at the beginning and end of the experiments. The lengths of the body and the tail were taken at the time of death. The age of all animals was known. As far as possible, test animals and controls were from the same litter, and were killed at the same time. The animals subjected to starvation were killed in the advanced stages of inanition, most of them when the animal was near death.

The animals submitted to asphyxiation were placed on a glass plate and covered with a bell jar of about 1000 cc. capacity. The chamber was made air tight by means of vaselin spread around the juncture of plate and bell jar. Six to seven hours elapsed before the rats were asphyxiated.

The thirty-four rats were divided into the following groups: nine were given no food, but allowed water; one was given neither food nor water; one was a new-born and not allowed to nurse.

Through the kindness of Prof. J. F. McClendon, four rats were obtained which had been fed on diets deficient in water-soluble A vitamine in various degrees. I am likewise indebted to Prof. R. Adams Dutcher for two rats, one fed upon an exclusive diet of gelatin for thirty days and the other for the same length of time on an exclusive diet of zein. Seventeen normal rats were used as controls.

The tissues of both test rats and control animals were fixed in the same manner and simultaneously dehydrated and imbedded in paraffin.

Bensley's acetic-chromic-osmic and Regaud's formalin-bichromate fixers were used. Sections were cut 2 and 3μ thick, and mounted in a series of ten or twelve to a slide. In some cases test and control tissues were mounted on the same slide—a method which gave the same staining technique for each.

The sections were stained by the acid-fuchsin-methyl green method of Bensley.

OBSERVATIONS

At the outset it may be well to emphasize the great variation found in the form and number of mitochondria in both the test and control tissues, due in part to the difficulty in securing uniformity of technique. Not all the cells of the epithelium of the test animals exhibit the modifications which are described. There are areas in the epithelium in which the cells show evidence of necrosis as a result of injury due to experimental conditions. In such circumscribed regions mitochondrial changes in form and number were apparent, especially in the deeper portions of the mucosa.

The normal stomach. In the gastric glands the mitochondria of the chief cells are short, straight rods. In most of the cells one may also find spherical mitochondria, but only a few to a cell. The spherical forms present the appearance of having been separated from the rod-like forms. Occasionally there is a linear arrangement of such spheres, as if a whole rod had become segmented. The rods vary from 2 to 5μ in length and the spheres from five-tenths to eight-tenths of a micron in diameter. The mitochondria are in most cells uniformly distributed throughout the cytoplasm. In exceptional cases there is a peripheral condensation, or grouping of the mitochondria, chiefly at the base of the cell.

Because of the difficulty in distinguishing between the acidophile secretory granules and the mitochondria of the parietal cells, no special study was made of these cells. Satisfactory

results in case of these cells could be obtained only by the use of the intra vitam stains. The cells of the foveolae and the surface epithelium have distinctly more mitochondria in them than do those of the glands. The mitochondria are uniformly distributed throughout these cells, and the size of the mitochondria is very nearly the same as of those in the chief cells.

The stomach of test rats. A study was made of the stomach in four rats fed for periods from 89 to 105 days on a diet variably deficient in water-soluble A vitamine. The chief cells of the gastric glands, in areas evidencing injury, exhibit changes in the mitochondria. This is especially true in case the diet is markedly deficient in the vitamine. The rod-like forms of mitochondria are entirely lacking, although a few spherical mitochondria occur. The cytoplasm of such cells exhibits a fine vacuolization at the periphery towards the lumen of the gland. Occasionally one finds this vacuolization throughout the cell. In the surface epithelium and the gastric foveolae the mitochondria show no well-marked or constant changes.

In the gastric glands of the two rats which had been fed on a diet of gelatin or zein, no mitochondria were found in the chief cells of the rather extensive necrotic areas.

Similarly in the rats subjected to acute inanition and in the last stages of starvation, no mitochondria occur in the chief cells of degenerated areas. Even in areas not exhibiting marked degeneration there are few if any mitochondria to be noted.

The cells of the foveolae and the surface epithelium, in all the experimental rats mentioned above, do not show as marked changes in the mitochondria. In those of the acute starvation series the rods are replaced to some degree by spheres. In but very few cases was it possible to find marked changes in the mitochondria of the cells of the foveolae and surface epithelium.

Observations upon the stomachs of asphyxiated rats show similar changes in the mitochondria of the chief cells, especially in areas evidencing injury. There are no rods, but spheres are present and apparently in reduced number. The cytoplasm of such cells is more or less vacuolated, resembling this condition in the cells of the other experimental animals. The cells of the

foveolae and the surface epithelium show no changes in the mitochondria.

The normal duodenum and pancreas. In the normal rats the mitochondria in the cells of the glands of Lieberkühn of the duodenum resemble those of the chief cells of the stomach. They are somewhat shorter, however, measuring from 2 to 4μ in length. Their distribution in the cells is likewise similar to that of the chief cells of the stomach. The epithelial cells of the villi resemble those of the foveolae and surface cells of the stomach epithelium, in so far as the mitochondria are concerned.

The mitochondria of the pancreas cells appear as long, straight rods. Their length is about twice that of those in the chief cells of the stomach. They are uniformly distributed throughout the protoplasm in the vicinity of the nucleus. The protoplasm of the cells nearest the lumen of the pancreatic alveolus contains secretory granules more frequently than it does mitochondria.

In the rats fed upon a vitamine-deficient diet the gland cells of the duodenum show spherical more frequently than rod-like mitochondria. Very often both spheres and rods occur in the same cells, but the rods are always fewer in number.

In acute inanition the mitochondria are usually absent in the cells of the glands of Lieberkühn and in the villus epithelium they are apparently decreased in number.

In the asphyxiated material there is no appreciable change in the mitochondria in the cells of either the glands or the surface epithelium of the villi.

The pancreas of the experimental animals does not exhibit abnormal areas in which the cells show evidences of injury such as occur in the stomach and duodenum. In vitamine deficiency the mitochondria are present in the gland cells, but the number of rods is decreased, most of the mitochondria being spherical in form. In the pancreas of animals suffering from acute inanition no rods occur. All of the mitochondria appear spherical in shape. Asphyxiation does not appear to modify the mitochondria in shape or number.

Because of the minuteness of the mitochondria in the pancreatic islet cells, no special study of them was attempted in these cells.

CONCLUSIONS

Vitamine deficiency and acute starvation may produce changes in the mitochondria in the gastro-intestinal epithelial cells and in the gland cells of the pancreas. Asphyxiation apparently does not produce such marked changes.

The amount of injury to the cell must be rather severe in order to bring about such changes. Cowdry ('20) reached the same conclusion from experiments upon plant rootlets.

The changes observed may involve: 1) a transformation of mitochondria from rod-like to spherical forms; 2) an apparent reduction in number of the mitochondria; 3) or even the total disappearance of mitochondria from the cells.

Because of the difficulty in obtaining uniformity of technique and the extreme variations observed in the staining reactions even in the normal cells, it is evident that great caution should be observed in drawing conclusions as to the effect of environmental changes upon mitochondria.

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Resumen por los autores, H. Cummins y J. Sicomo

Un caso de hiperdactilismo; duplicación bilateral del pulgar y primer metatarsiano de un negro adulto.

En este trabajo se describen los dos piés, ambos con seis dedos. Los dos dedos más mediales de cada pié son los pulgares. Las líneas de fricción son semejantes en los dos pulgares de cada pié. Las líneas en la planta no están modificadas. Las falanges de los pulgares y el primer metatarsiano están por completo duplicados. En los tendones del extensor y flexor largos de los pulgares existe una bifurcación, para su inserción en los dos pulgares, y en el pié izquierdo solamente, el vientre más medial del extensor corto de los dedos y el adductor están también bifurcados. En el pié derecho el abductor, adductor, y el flexor corto de los dedos se insertan salamente sobre el pulgar medial; en el izquierdo el abductor y el vientre medio del flexor corto de los dedos se insertan solamente sobre el pulgar medial, junto con una pequeña contribución del adductor, mientras que este último casi entero y todo el vientre lateral del flexor corto de los dedos están relacionados con el pulgar lateral. El curso de los vasos y nervios no presentan cambio que pudieran relacionarse germinalmente con el hiperdactilismo. Se considera a la anomalía descrita como el resultado de una variación germinal solamente en relación con la iniciación de su desarrollo. Como consecuencia de la inestabilidad germinal tuvo lugar, suponen los autores, una reproducción de los determinantes de los huesos del pulgar y de la epidermis durante la vida embrionaria temprana. Con la ulterior diferenciacion de los músculos, vasos y nervios estas estructuras se adaptaron, imperfectamente en el caso de los primeros, al doble movimiento del pulgar.

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A CASE OF HYPERDACTYLISM: BILATERAL DUPLICATION OF THE HALLUX AND FIRST METATARSAL IN AN ADULT NEGRO

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NINE FIGURES

Among the cadavers received in the anatomical laboratories of Tulane University in 1921 there was one hyperdactylous subject. The subject was a male negro, aged about fifty years, who died of chronic interstitial nephritis and chronic pleurisy. The body exhibited no external abnormalities other than the occurrence of six digits on each foot. Skiagrams identified the extra toes as halluces, and moreover demonstrated complete duplication of the first metatarsal in either foot. In spite of the large number of hyperdactylous cases reported, the opportunity for dissection of such material is relatively rare, especially in the adult. For this reason, and because of the unusual completeness of duplication in the case described, the results of its study were thought to be worthy of record. Information relating to the subject in life is not available. Therefore it is impossible to trace the inheritance of hyperdactylism in his family or to ascertain the degree of usefulness or inconvenience occasioned by the added toes.

Effective embalming of the body had been accomplished before the feet were removed. With the aim of handling them more readily in subsequent study, the feet were amputated at a level of about 5 cm. above the ankles. Although the legs were retained, to be dissected in the event that atypical muscles or other structures would require tracing upward, the occasion for dissection at higher levels did not arise. Obviously, actual prints would have been ideal material for the observation of epidermal patterns. But the hardening consequent to embalming, which

rendered every surface irregularity incompressible, and desquamation of the superficial epidermis proved to make successful prints impossible. Casting of the soles in wax was likewise unsuccessful. It was finally necessary to resort to direct study of the plantar skin and the use of drawings as records for publication. These drawings, reproduced as figures 3 and 4, are based upon careful observation of the patterns under a hand lens. Lines of interpretation were followed with ink directly upon the skin. In drawing, the interpretation lines were first inserted, their locations within the sole outline being determined by measurement; then the courses of cristae within individual areas were added in a diagrammatic manner. Wilder's paper of 1916 was used as a guide in the study of these patterns. The method of dissection requires no comment. Full notes were made as the dissection progressed, and at the same time figures 7, 8, and 9 were made in their present form, drawn by one of us and checked by the other. In studying skeletal parts use was made of the skiagrams as well as the actual bones. While other texts on descriptive anatomy were consulted, Morris' Human Anatomy was used as a guide. Lymphatics, deep veins, and ligaments were not dissected, but other structures were dissected in entirety in both feet. In many cases no mention has been made of structures which are typical, but in no case has note of a variation been omitted.

The terms *medial hallux* and *lateral hallux* are here used because each is a complete digit and of hallucal identity. In the same manner, the terms *medial first metatarsal* and *lateral first metatarsal* are applied to the bones which represent a doubled first metatarsal. *Interhallucal* is, in the restricted sense which its meaning implies, comparable to interdigital. Enumeration of the typical digits, of the metatarsals associated with them, of the interosseous spaces—in short, of all structures which are numbered in ordinary description of the normal foot—follows the terminology of descriptive anatomy.

Prof. H. H. Wilder has examined the material on epidermal patterns, including the plantar skin from both feet and our drawings and descriptions. The writers are indebted to him for

this kindness and to Dr. A. Henriques, of New Orleans, for the skiagrams.

EXTERNAL FEATURES

In their superficial appearance both medial and lateral halluces conform to the nature of fully developed digits and, further, they bear the characteristics of halluces. The medial hallux is a hallux without question, because of its large size, medial position, single phalangeal joint, and broad heavy nail. The lateral hallux is no less a great toe; in spite of its smaller size and aberrant position, it possesses the shape, single phalangeal joint, and broad nail of a hallux. In either foot the lateral hallux is in correct linear relation to the long axis of the foot. On the right foot the medial hallux is medially rotated, although its long axis is in line with the other digits. The left medial hallux is in such pronounced abduction as to project almost vertical (in a horizontal plane) to the long axis of the foot. These differences in position are to be explained below on the basis of variations in distribution of muscle insertions to the right and left medial halluces. Pronounced webs occur in all the interdigital areas of either foot and in the interhallucal area of the right foot, but not in that of the left. Owing to its supernumerary metatarsal and digit, the distal portion of each foot is wider than normal. On the medial margin, of the right foot only, there is a large prominence produced by the head of the medial first metatarsal. Owing to the hardening after embalming, any accurate determination of the contact area in life is impossible. Contact areas, judging from the hardened feet, must have been limited, restricted in size by the unusual height of the arch. Prints of the contact areas are reproduced in figures 1 and 2, which also show the general contour of the feet and positions of the digits.

Epidermal patterns are represented in figures 3 and 4. Notwithstanding slight differences in details of configuration, the hallucal patterns are alike in the two feet. The pattern consists of a single triradius and an open field, corresponding to Wilder's type BC. The first interdigital area in either foot is a loop. In the right foot the narrowed proximal portion of the loop curves

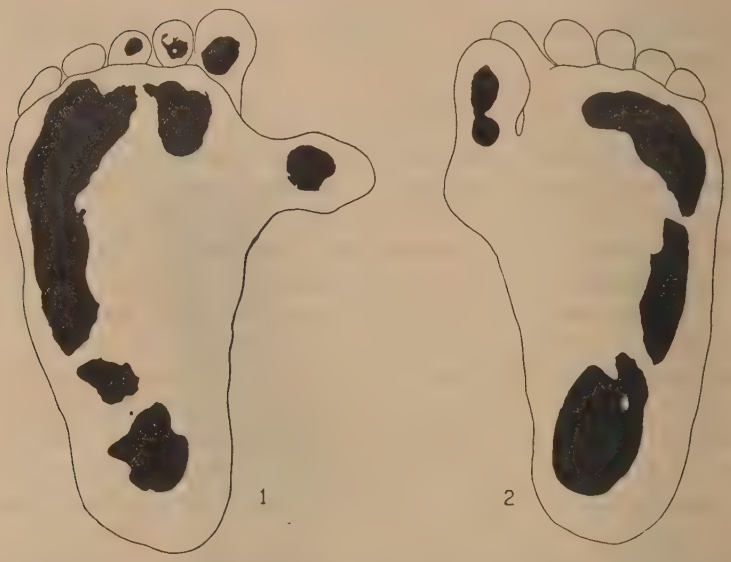


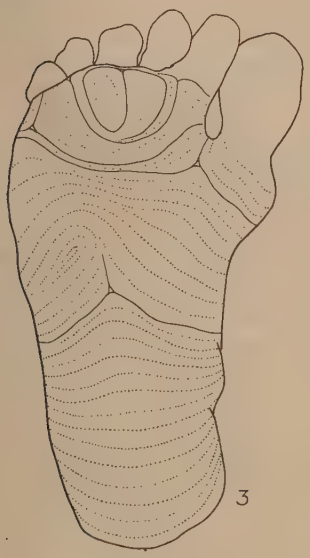
Fig. 1 Contact area of the left foot; an impression made by firmly pressing the completely inked sole of the hardened foot upon a rigid plane surface.

Fig. 2 Contact area of the right foot; made as above.

Measurements (in millimeters)

	RIGHT	LEFT
Greatest length of foot, measured from posterior extremity of heel to the furrow at bases of digits	211	209
Width of sole, in region of heads of metatarsals	115	111
Width of sole, in region of ankle	71	78
Greatest diameter of medial hallux	31	31
Diameter of medial hallux at its base	22	33
Length of medial hallux	44	45
Greatest diameter of lateral hallux	18	23
Length of lateral hallux	31	31
Maximum elevation of roof of arch, above level of contact area	26	28
Elevation of apex of lateral malleolus, above level of contact area	94	84
Elevation of apex of medial malleolus, above level of contact area	92	82

around the lateral border of the second interdigital area, and its ridges then become continuous with the transversely placed ridges in the depressed region of sole area at the bases of the toes. In the left foot the loop becomes confluent with the third interdigital area. In both feet the third interdigital area is an open field; in the right foot it opens at the distal margin of the



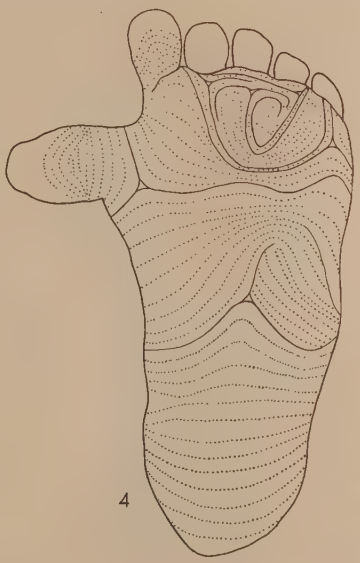


Fig. 3 Epidermal patterns of the sole, right foot; triradii and interpretation lines unbroken; courses of friction ridges shown in dotted lines.

Fig. 4 Epidermal patterns of the left foot, including digital patterns of the halluces; drawn as in the right foot.

sole area lateral to the hallucal pattern, and in the left flows into the loop of the first interdigital area. An extensive hypothenar pattern occurs on each foot, the figure being a large loop and triradius, with the opening of the loop lateral. This pattern is within the tread area. A hypothenar loop occurs in a little over half of all known sole prints. When present it usually opens medially, and often is not within the tread area. The pattern in this case thus is an unusual one with reference to its

lateral opening and its position well down on the sole. A rudimentary thenar pattern is present on each foot, indicated by the divergence of friction ridges as they course toward the medial margin of the sole. No remnant of a calcar pattern is visible. Friction ridges on the medial and lateral halluces of the one foot are counterparts of each other, and they are alike on the two feet. They are arranged in straight transverse lines at the bases of the halluces; distally they become arciform, with the convexity distal. No indications of digital triradii are to be found. Formulation of the patterns follows:

Left foot: BC. L. W. O. H.
Right foot: BC. L. + III. W. O. H.

BONES

In their morphology and number the phalanges of the medial and lateral halluces are typical in both feet. And each of the two first metatarsals of each foot is in size and morphology like the normal single first metatarsal (skiagrams, figs. 5 and 6). Distal phalanges of the right and left medial halluces are similar in size and shape, as are the distal phalanges of the lateral halluces. The proximal phalanx of the left medial hallux is larger than that of the right. On the left foot, the proximal phalanges of the two halluces, at their point of articulation with the corresponding metatarsals, diverge from each other, while on the right foot they converge. The proximal phalanx of the right medial hallux is medially rotated upon its long axis. In the left foot, the facet on the medial first metatarsal for articulation with the proximal phalanx of the medial hallux is shifted proximomedially, and in the right foot the corresponding facet is situated proximolaterally. The mutual contact surfaces of the two first metatarsals are more extensive in the left foot than in the right. In the left foot, articular surfaces and joint capsule are lacking in the region of contact, the metatarsals being held together by dense connective tissue in amount great enough to allow very little movement, if any. In the right foot, articular surfaces and joint capsule occur at this junction. Proximally, the medial first metatarsal of each foot articulates with the first

cuneiform, but the articular facet of the right one faces farther proximolaterally than does the similar facet of the left. The lateral first metatarsal of the left foot articulates proximally with the first cuneiform and with an accessory bone. This accessory bone is a triangular pyramid in shape, its base facing dorsally. It is wedged between the distal extremities of the first and second cuneiforms, articulating with them as well as with

Fig. 5 Skiagram of the left foot; rayed from the dorsal aspect.
Fig. 6 Skiagram of the right foot; rayed from the dorsal aspect.

the lateral first metatarsal. The lateral first metatarsal of the right foot is extended proximally as a wedge-shaped process fitting between the distal extremities of the first and second cuneiforms. If the process were transversely separated from the body of the metatarsal, it would have the same size, shape, and articulations as the accessory bone of the left foot. From their point of articulation with the tarsus, the medial and lateral first metatarsals of the right foot diverge, and this divergence is rendered apparently greater by the constriction of their shafts. Although there is

some divergence of the same bones in the left foot, the angle is not so great and is apparently lessened through the more slight constriction of their shafts. In either foot there are sesamoids related to the heads of both first metatarsals.

MUSCLES

M. abductor hallucis in both feet is restricted in insertion to the medial hallux, with no indication of even a diffused or aponeurotic insertion upon the lateral hallux. The area of insertion, at the base of the proximal phalanx, is typical. The origin of the abductor is typical, except that a larger than usual proportion of its fibers originate from the fibrous arch on the deep surface of the muscle; the arch itself is of uncommonly great proximodistal extent.

M. flexor hallucis brevis in either foot is divided, as usual, into medial and lateral bellies. LEFT: The lateral belly is much the larger of the two. It arises in common with the adductor from the first, second, and third cuneiforms, from the lateroplantar aspect of the base of the lateral first metatarsal, and from the peroneus longus tendon, but not from the plantar calcaneocuboidal ligament. Insertion of the lateral belly is confined to the lateral hallux, at the base of its proximal phalanx. The medial belly has a dual origin, from the first cuneiform and from the fibrous arch on the deep surface of the abductor. It is readily separable into two fasciculi, medial and lateral. The origin of the lateral fasciculus is from the first cuneiform; its tendon of insertion accompanies and is fused with those of the medial fasciculus and abductor, ultimately inserting upon the medial aspect of the proximal phalanx of the medial hallux. The medial fasciculus arises only to a limited extent from the first cuneiform, most of its fibers originating in common with that portion of the abductor which comes from the fibrous arch on its deep surface. It inserts in common with the lateral fasciculus and abductor, wholly upon the medial hallux. RIGHT: The lateral belly is intimately fused with the oblique head of the adductor, and inseparable from it. Insertion, like the adductor of this foot, is confined to the medial hallux. The medial belly

is fused throughout its length with the abductor, is not separable into two fasciculi, and inserts wholly upon the medial hallux.

M. adductor hallucis in each foot is separated into the usual transverse and oblique heads, both of typical origin. LEFT: Tendons of insertion from the two heads are fused together and, with the tendon of the lateral belly of the flexor hallucis brevis, are inserted upon the base of the proximal phalanx of the lateral hallux. In addition, the oblique head gives rise to a small tendon which, between the bases of the proximal phalanges of the two halluces, bifurcates into a smaller medial division and a larger lateral one. The medial division inserts directly upon the plantar aspect of the proximal phalanx of the medial hallux at its base. The lateral division is continued into the longitudinal tendinous band in the tendon sheath of the flexor hallucis longus, described under that muscle. RIGHT: The muscle is much larger than in the left foot, especially its transverse head. Insertion is confined to the medial hallux.

M. flexor hallucis longus. LEFT: The tendon of insertion is bifurcated and inserts upon the bases of the distal phalanges of both halluces, as shown in figure 9. Its synovial sheath is likewise divided as it accompanies the two divisions beyond the common tendon. Proximal to the point of bifurcation, on its plantar surface only, the common tendon is superficially divided into medial and lateral halves by a slight longitudinal furrow, visible almost to the point of fusion of this tendon with that of the flexor digitorum longus. When the common tendon is forcibly split along the line of this furrow, small bundles of tendon fibers of the two components are found to interlace, but in spite of their presence the separation of the common tendon clearly follows the superficial furrow. The relation of the common tendon to the flexor digitorum longus is described under the latter muscle. In the dorsal aspect of the sheath which encloses the tendon to the lateral hallux there is a condensed longitudinal band of tendinous fibers. Proximally, most of these fibers are attached to the base of the proximal phalanx of the lateral hallux, but a few radiate medially to reach a similar attachment upon the medial hallux. Distally, this band is fused to the base

of the distal phalanx of the lateral hallux. A contribution to the band from the oblique head of the adductor has been noted above. RIGHT: The tendon is slightly fused with that of the flexor digitorum longus, at the point where it is crossed diagonally by the latter. Distal to the level of fusion the flexor hallucis longus tendon divides into three bundles, of which the one most medial is the largest. This medial bundle extends distally as far as the middle of the two first metatarsals, where it bifurcates into medial and lateral tendons; these insert upon the medial and lateral halluces, respectively. The tendon to the medial hallux is larger than the lateral one. The intermediate one of the three bundles, along with the above-mentioned lateral tendon of the medial bundle and with a slip from the flexor digitorum brevis, inserts upon the lateral hallux. The lateral bundle simulates a tendon of the flexor digitorum longus; it inserts upon the second digit and provides origin for the first and second lumbricals.

M. extensor hallucis longus. LEFT: The tendons of this muscle are represented in figure 7. Its tendon of insertion is bifurcated, and an aponeurosis is stretched between the two divisions. For the most part, the fibers of the common tendon are continued distally to insert upon the phalanges of the lateral hallux, although some fibers are contributed to the aponeurosis. The aponeurosis is attached not only to the two divisions of the extensor tendon, but also to the opposed surfaces of the proximal phalanges of both halluces and to the heads of both first metatarsals. The division to the medial hallux is aponeurotic near the common tendon, with indications of four condensed bundles of fibers which become convergent as they extend distally; insertion is at the base of the distal phalanx. The common tendon sends a long thin slip to that tendon of the extensor digitorum longus which inserts upon the second digit. RIGHT: In this foot the common tendon bifurcates, but the divisions are much more distinctly separate than in the left. Distally there is no aponeurosis stretched between the two divisions, and each division is a clearly separate tendon with normal insertions upon the phalanges of either hallux. Proximally, in the angle between the

two divisions, there is a slight aponeurosis which is not attached to the adjacent bones as in the left foot.

M. extensor digitorum brevis. LEFT: The most medial belly, sometimes called extensor hallucis brevis, possesses a tendon which bifurcates into medial and lateral divisions, with an aponeurosis between them. The medial division enters the aponeurosis of the extensor hallucis longus, and as a distinct fasciculus

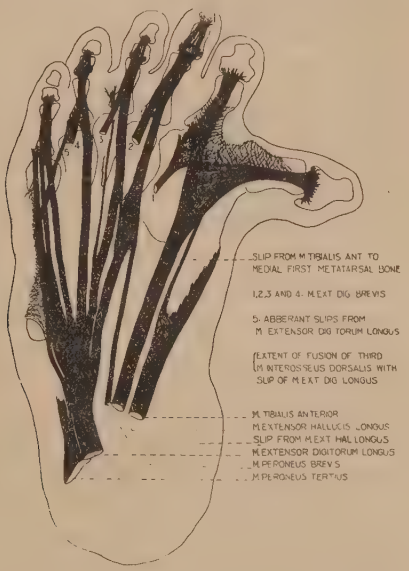


Fig. 7 Tendons of the dorsum, left foot.

is continued distally to insert upon the medial hallux at the base of its proximal phalanx. The lateral division inserts upon the head of the lateral first metatarsal and base of the proximal phalanx of the lateral hallux. The aponeurosis is continuous with that of the extensor hallucis longus, and loses its identity within the common aponeurosis thus formed. RIGHT: Here the muscle belly is typical, and inserts wholly upon the lateral hallux.

M. flexor digitorum brevis is normal in the left foot, but in the right possesses five bellies. The four lateral ones apparently represent the typical muscle, while the most medial belly inserts upon the lateral hallux.

M. flexor digitorum longus. LEFT: This muscle sends a slip from its tendon to that of the flexor hallucis longus, the level of origin of the slip being slightly proximal to the insertion of the quadratus plantae (superficial portion of the medial head) into the tendon of the flexor digitorum longus. The position and direction of fibers in the slip indicate that they are destined to reach the medial hallux only. There are two distinct strata in the tendon, superficial and deep. The deep stratum is composed of fibers issuing from the tendon of the flexor hallucis longus, at about the same level as the slip to this tendon, and continuing distally as two tendons inserting upon the second and third digits. Tendons to the fourth and fifth digits are from the superficial stratum, the one to the fifth digit being small and rudimentary. RIGHT: Coincident with the replacement of its most medial tendon by a slip from the flexor hallucis longus, this muscle has only three tendons of insertion. The most medial of the three sends a slip into the lateral bundle of the flexor hallucis longus. Also small bundles of fibers pierce directly through the tendon of the flexor hallucis longus, and are continued distally as longitudinal fasciculi to reenter the tendon to the third digit. The most lateral of the three tendons is unusually large; it receives a slip from the flexor digitorum brevis.

M. quadratus plantae in either foot is divided into the usual medial and lateral heads. LEFT: The medial head is separated into two strata, superficial and deep. Insertion of the former stratum is upon the lateral margin of the plantar surface of the flexor digitorum longus tendon, superficial portion. The deep stratum inserts upon the lateral margin of the deep portion of the same tendon. The lateral head inserts like the deep stratum of the medial head, but more distal. RIGHT: Insertion of the medial head is upon the tendon of the flexor digitorum longus, on its lateral margin and dorsal aspect just proximal to the trifurcation of the tendon. The lateral head inserts upon the

lateral margin of the lateral bundle of the flexor hallucis longus and upon the three tendons of the flexor digitorum longus.

M. peroneus longus in either foot is typical, but that portion which normally inserts upon the first metatarsal is here limited to the medial first metatarsal.

M. interossei do not occur between the two first metatarsals of either foot.

SUPERFICIAL VEINS; ARTERIES

The courses of superficial veins are alike in the two feet, with no deviations of note other than provision for drainage of both halluces. These vessels of the dorsum of the left foot are shown in figure 8.

A. dorsalis pedis. LEFT: The first dorsal metatarsal (a. dorsalis hallucis) arises in line with the navicular, so far proximal as to carry the medial tarsal branch with it. Its primary distribution is normal. A branch to the deep structures in the interosseous space between the two first metatarsals arises from it, in line with the bases of the first metatarsals. It gives no supply to the medial hallux. RIGHT: General relations of a. dorsalis pedis are as in the left foot, but the second dorsal metatarsal does not originate from the dorsal arch. Instead, it comes from the plantar arch, issuing through the proximal extremity of the second interosseous space, to be distributed in the manner of a second dorsal metatarsal.

A. plantaris lateralis and ramus plantaris profunda. LEFT: The former vessel is of uncommonly small diameter. From it the following branches originate, in order beginning laterally: 1) A branch which courses distally on the plantar surface, bifurcating, in line with the head of the fifth metatarsal, into medial and lateral terminals. The lateral supplies the lateral aspect of the fifth digit and the adjacent plantar surface and lateral margin of the foot. The medial terminal supplies the opposed surfaces of the fourth and fifth digits. 2) A metatarsal supplying the opposed surfaces of the third and fourth digits. 3) A branch supplying the deep structures adjacent to the distal portions of the first and second interosseous spaces. 4) The

continuation of the arch medial to the last-named branch is an extremely small artery, which, on the lateroplantar aspect of the base of the lateral first metatarsal, joins the deep plantar branch of the dorsalis pedis. From the medial aspect of this junction there is an artery, which, because of its large size and linear relation to the deep plantar, is considered to be a continuation of the deep plantar rather than of the plantar arch. This artery continues medially as far as the line of contact between the two first metatarsals, where it turns distally in the interosseous space between them and is joined by the 'deep branch proper' of the medial plantar. The common trunk distal to the junction, larger in diameter than would be expected of a metatarsal, is distributed to the interhallucal area and opposed surfaces of the two halluces. RIGHT: As in the left foot, the contribution of the lateral plantar artery to the plantar arch is reduced not only with reference to the diameter of the vessel, but also as to the distance which it extends medially and the number of branches originating from it. There are three branches of the lateral plantar; they are, in order beginning laterally: 1) A branch to the lateral aspect of the fifth digit and the adjacent plantar and lateral region of the foot. 2) A branch which perforates the proximal extremity of the first interosseous space and is distributed as a dorsal metatarsal (noted under a. dorsalis pedis). 3) The lateral plantar artery terminates by anastomosing with the lateral trunk of the deep plantar. The deep plantar issues through the proximal end of the first interosseous space, dividing immediately into two large trunks, lateral and medial. The lateral trunk gives rise to two branches, lateral and medial, at the point of junction of this trunk with the lateral plantar. The lateral branch almost at once divides into two plantar metatarsals, coursing, respectively, in the fourth and third interspaces. The medial branch is distributed as a plantar metatarsal to the second interspace. Distally, the most medial two of the three plantar metatarsal branches receive anastomoses from the superficial branch of the medial plantar. The medial trunk crosses the base of the lateral first metatarsal, and then turns distally in the interosseous space between the two first metatar-

sals; at the middle of this space it divides into two branches, plantar and dorsal. The plantar branch anastomoses with the deep branch of the medial plantar; beyond the anastomosis it runs superficial to the insertion of the adductor hallucis, and then anastomoses with the dorsal branch. Two digital branches, distributed to the opposed surfaces of the halluces, arise from the plantar branch. The dorsal branch turns dorsally in the interhallucal area, first giving rise to a branch reaching the base of the medial hallux, then arching toward the plantar surface, where it enters into anastomosis with the plantar branch. In its course toward the plantar surface it gives origin to a digital branch to the medial side of the lateral hallux. It is evident that the anastomosis between the dorsal and plantar branches of the deep plantar results in the formation of an arterial ring which also receives a contribution from the deep branch of the medial plantar. Both heads of the adductor and the lateral belly of the flexor hallucis brevis are encircled by the ring, near their insertions upon the medial hallux.

A plantaris medialis. LEFT: From the superficial branch there are two branches of especial interest in that they replace two of the metatarsal arteries typically originating from the plantar arch. These two arteries supply, respectively, the opposed surfaces of the second and third digits and the opposed surfaces of the lateral hallux and second digit. The deep branch, in line with the middle of the medial first metatarsal, divides into a deep branch proper and a medial digital branch. The latter supplies the medial and plantar aspects of the medial hallux. The deep branch proper continues distally, ultimately joining the deep plantar artery. RIGHT: From the superficial branch there are three small branches anastomosing with the most medial three plantar metatarsals. The deep branch supplies a digital branch to the medial hallux.

NERVES (figs. 8 and 9)

The *sural* in either foot is a little larger in diameter than usual. It descends on the lateral border of the tendon Achilles, posterior to the lateral malleolus, and before turning distally

it gives a large branch which fans out on the lateral surface of the heel; this branch takes the place of the usual lateral calcaneal branches. Distal to this branch the sural is continued along the lateral border of the foot as the lateral dorsal cutaneous nerve, supplying many small branches to the region through which it courses. Ultimately the nerve divides into two dorsal digital branches, one for the lateral surface of the fifth digit and one for its dorsum.

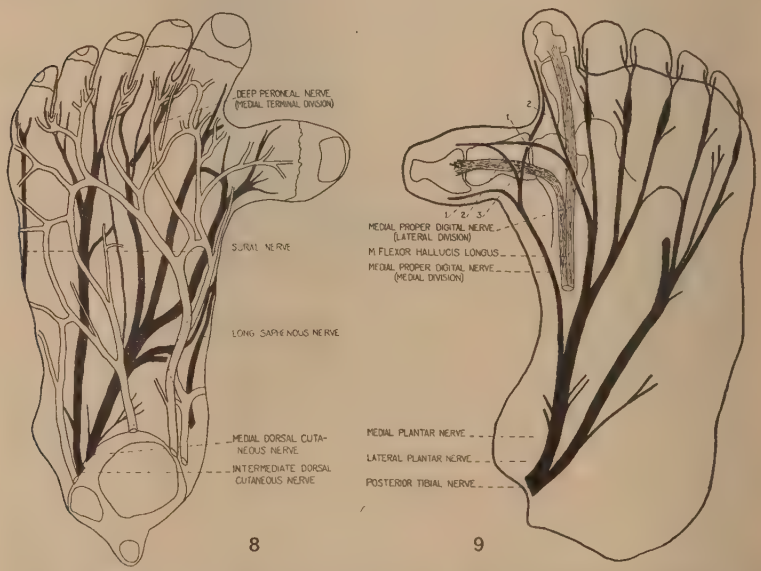


Fig. 8 Superficial veins and nerves of the dorsum, left foot; veins in open lines and nerves solid.

Fig. 9 Plantar nerves and tendon of the flexor hallucis longus, left foot.

The *intermediate dorsal cutaneous* is alike in both feet, with one exception. The nerve divides distally into three dorsal digital branches: the first, from lateral to medial, innervates the adjacent sides of the fourth and fifth digits; the second, the adjacent sides of the third and fourth digits, and the third, the medial side of the third digit. Slightly proximal to the point of origin of these branches, the common trunk gives rise to a prominent

branch which anastomoses with a branch of the medial dorsal cutaneous, and this combined nerve anastomoses distally with the third dorsal digital branch of the intermediate dorsal cutaneous. These anastomoses are lacking in the right foot.

The *medial dorsal cutaneous* divides into five branches in the left foot, only four in the right, the branch lacking in the right foot being the one entering into the anastomosis mentioned above. Beginning laterally, the first branch supplies the lateral surface of the second digit; the second and third branches anastomose distally and innervate the medial surface of the lateral hallux, the interhallucal area and the lateral, dorsal and medial surfaces of the medial hallux; the fourth branch anastomoses with a direct continuation of the long saphenous, and both innervate the medial aspect of the foot.

The *deep peroneal, medial terminal division*, in either foot, retains its normal position with reference to the second digit, between it and the lateral hallux, with no branches extending to the medial hallux.

The *medial plantar* in either foot possesses two branches which are comparable to the typical single medial proper digital branch; these are for convenience designated the medial and lateral divisions of that branch. The medial division divides into three digital branches which supply the medial and lateral surfaces of the medial hallux and the medial surface of the lateral hallux. The lateral division terminates in two branches, the first of which anastomoses with the second one of the medial division to supply the lateral surface of the medial hallux. The second branch anastomoses with the third one of the medial division and supplies the medial surface of the lateral hallux.

DISCUSSION

Annandale classifies supernumerary digits in four groups: 1) deficient, loosely attached by a narrow stalk to the hand or foot or to another digit; 2) more completely developed, free distally and articulating with the head or sides of a metacarpal, metatarsal, or phalanx; 3) completely developed and separate, and, 4) intimately united, longitudinally, with another digit, and either

provided with a metacarpal or metatarsal of its own or articulating with the head of one common to it and another digit. The case described is to be referred to class 3, since each hallux is separate and completely developed, even to the extent of possessing a metatarsal of its own. That the two most medial digits of either foot are halluces is demonstrated particularly by their external features, bones, and muscles.

Concerning the factors underlying the production of extra digits, at least three explanations have been advanced. An older view accounts for the anomaly on the basis of reversion. But, as is indicated by the facts briefly outlined in the following extract from Prentiss ('06), the theory is untenable in accounting for hyperdactylism in man or other pentdactylous mammals.

> We may assume that the primitive and typical mammalian foot was pentdactyl, in spite of Bardeleben's contention that the progenitors of the mammalia possessed not five, but seven digits. Bardeleben's assumption was based upon the observation that certain mammals, the whale, for example, have more than five digits; that among five-toed forms six and seven digits occasionally occur; and that in many species small cartilages are present on each side of the hand and foot. These cartilages Bardeleben regards as digital rudiments, and the occurrence of extra digits is explained by him as reversion, a 'turning back' through heredity, to ancestral conditions. Unfortunately, the facts do not support this beautiful theory. Paleontology tells us that the forerunners of the mammalia possessed only five toes. Embryology has shown that the sixth digit of the whale, and the cartilages which Bardeleben supposes to be digital rudiments, develop secondarily some time after the typical five digits have appeared. Finally, observations have proved that the extra digits which occur in polydactylism do not develop from Bardeleben's 'digital rudiments,' but originate in an entirely different manner. We may, therefore, assume that the primitive mammalian foot was pentdactyl, and this being so, the occurrence of six or seven digits on a foot normally five-toed can not be attributed to reversion, unless we assume with Albrecht that it is reversion to the many-rayed fins of the Elasmobranch fishes, an absurd supposition.

The second causal factor postulated is that of mechanical influences which distort the embryonic hand or foot. It is not unlikely that some cases of imperfectly developed supernumerary digits, especially if unilateral, might be the result of compression or constriction by amniotic bands. In fact, Ahlfeld (cited by Prentiss) "has observed that digital duplications may

be caused 'in utero' by pressure from the thread-like growths of the amnion." The very existence of a family history of hyperdactylism, present in most cases, would argue against the operation of such a factor, as would the usual bilateral occurrence (Broman) of the duplication and the much more frequent involvement of the first and fifth digits rather than the intervening ones (Prentiss). Still more conclusive argument against a general postulation of mechanical factors is furnished in the existence of hyperdactylous identical twins. Stockard presents a case of identical twins in which both twins possess apparently the same type and degree of hyperdactylism—six digits on each hand and foot. In the same connection, Danforth describes the left hands of a pair of twins, possibly identical, each having a supernumerary fifth digit which is small and imperfectly developed.

We are led, then, to the probably almost invariable source of hyperdactylism, namely, an intrinsic factor or complex of factors, non-atavistic in nature. The arguments set forth above as opposed to mechanical induction favor not only the assumption of intrinsic factors, but also possibly an almost universal operation of potentialities transmitted by the germplasm. However, hyperdactylism occurs in monsters (Gräfenberg) as well as in individuals who are otherwise normal, the genesis of such monsters being explained by Stockard on the basis of developmental arrest. In these cases it seems not unreasonable to assume that causative factors which are non-germinal, but which operate intrinsically in modifying the normal rate of development, may bring about the condition of hyperdactylism coexistent with deformities which are unquestionably non-germinal in origin.

Prentiss repeatedly states that the germinal factor is not productive of invariable particular duplications, but rather is only a tendency toward duplication, exhibiting itself in successive generations as variable types and degrees of hyperdactylism or even merely as increased size of the first or fifth digits. Both Broman and T. Lewis note the frequent association of hyperdactylism and syndactylism in the same individual; Prentiss ('10) describes a case of hyperdactylism associated with deficiency

of the frontonasal process, and a legion of cases of heritable developmental defects coexistent with hyperdactylism occur in the literature. Then is it not warrantable to conclude that hyperdactylism of germinal origin is the immediate result of an instability in the autonomous control of developmental processes, the heritable factor being the instability and not the particular duplication? There seems to be a parallelism in the results of this instability and defects induced by experimental modification of developmental rate. Stockard concludes that various types of experimentally produced defects may be obtained by identical treatment of the embryos, and, further, that the type of defect is dependent upon the time at which developmental arrest is induced by the treatment. If such a parallelism does exist, the type and degree of hyperdactylism may be dependent upon the period at which germinal instability comes into play. On the other hand, if there is no correspondence in the action of experimental arrest and germinal instability, the degree of instability may, conceivably, be measured by the type and degree of duplication. In either case, it is apparent that a certain amount of selectivity exists, in that the first and fifth digits are most frequently affected. Prentiss points out that these digits are in the process of modification and regression, respectively; he suggests that these digits are thus more unstable, more plastic, and hence would be the most common sites of variation.

Hyperdactylism in the case described is assumed to have been produced by germinal factors. It is not believed that there was provision in the parental germ cells for both halluces in toto, or, if the foregoing arguments hold, even for the particular duplication. Rather, the immediate cause is presumed to have been an instability, transmitted germinally, perhaps in the form of a modification in rate of development which occurred in very early embryonic development. From the anatomical findings it is concluded that this instability resulted in a complete duplication of the germinal determinants for hallucal epidermis, hallucal phalanges, and first metatarsal. Further, it is concluded that the same instability need not have directly influenced muscles, vessels, and nerves, that the adaptation of these structures

to the doubled hallucal environment could have been secondarily induced.

Conclusions drawn from observations on individual systems are summarized in the following paragraphs.

Friction ridge patterns of the sole show no variations concerned with the hyperdactylous condition. By virtue of its position, the medial hallux has appropriated the hallucal pattern. The pattern itself shows no cleavage, duplication or even attempted duplication. In the absence of any disturbance within the hallucal pattern, it seems that there must have been no germinal provision for accessory hallucal patterns correlated with the duplication. In embryonic development the physical separation of the hallucal epidermal area into two isolated digital areas must have been preceded or accompanied by readaptation of the epidermal determinants. Determinants for general skin of the hallux, its nail and digital friction ridge patterns must have completely reproduced themselves. Their reproduction could have been incited through the primary action of the developmental instability (arrest?), or secondarily through doubling of the hallucal environment, but unlikely by a direct germinal provision for two hallucal digital epidermal areas, the unmodified hallucal pattern being contraindicative.

Doubled sets of bones, structurally like those of the normal hallux and its metatarsal, must be, developmentally, the result of a qualitatively complete duplication of the determinants for bones of the single hallux and first metatarsal. The time at which such duplication occurred and even the sequence of ontogenetic events following it are a matter only of conjecture. Potentially, two sets of bones may have been present long before they were evident structurally, the reproduction of determinants for bones having been an early and direct effect of the developmental instability. Once formed, the hallucal phalanges and first metatarsals seem to have served as cores or points of reference about which other hallucal structures were developed. Bardeen ('10) describes the normal development of the foot bones. Their first appearance is in the form of a foot plate, a condensation of the formerly more diffuse mesenchyme in the

distal portion of the posterior limb bud appearing during the fifth week. Toward the end of the fifth week, five localized areas of still greater condensation appear within it, the digital rays. During the sixth and seventh weeks, each digital ray segments transversely into, first, a metatarsal, and then the phalanges of a digit. Coincidentally, anlagen of the separate tarsal bones appear within the proximal portion of the foot plate, becoming more distinctly outlined toward the end of the second month. In our case the complete development of individual bones would point to an extremely early appearance of the supernumerary toes. Perhaps when first condensed within the foot mesenchyme the foot plate may have been wider than normal, its most medial region bearing tissue for the development of two metatarsals instead of one and two sets of hallucal phalanges. With the condensation of digital rays, six instead of five may have been formed, each of the two most medial carrying the germinal nature of the typical most medial one. Or, perhaps five digital rays appeared within the foot plate, and the most medial one was cleft longitudinally into two. It seems unlikely that a cleavage much later than this could be accountable for the well-developed bones met with in both feet. The duplication apparently does not invade the region of the tarsus. However, the accessory bone of the left foot may be the result of an abortive duplication of the first or second cuneiform, which in the right foot was secondarily ankylosed with the lateral first metatarsal. More likely, the accessory bone represents the epiphysis of the lateral first metatarsal, isolated in the left foot and normally fused with the shaft in the right.

The absence of a germinal provision for muscles is inferred from the absence of interossei between the two first metatarsals, the failure to produce any new muscles and the lack of adaptation of some muscles to both halluces. As a consequence of the last two deficiencies, the halluces of either foot are provided with an unequally distributed musculature. In the right foot the abductor, adductor, and both bellies of the flexor hallucis brevis insert wholly upon the medial hallux. The same muscles are more evenly allotted to the two halluces of the left foot, where the

abductor, medial belly of the flexor hallucis brevis, and only a very minor portion of the adductor insert upon the medial hallux, leaving the major portion of the adductor and the entire lateral belly of the flexor hallucis brevis for the lateral hallux. The tendons of the long hallucal flexor and extensor are bifurcated and insert upon both halluces of either foot. The distribution of muscles is regarded as secondary, the variations described being induced through the relations of the developing muscles to the already doubled osseous environment. From Lewis' account of the embryology of the foot muscles ('10), it appears that isolation of individual muscles from the premuscle masses may be either coincident with or subsequent to the appearance of anlagen for the separate bony elements with which they later become related; but the selection of their definitive insertions naturally follows the differentiation of the bones upon which they insert. The developing bones may be considered as points of reference which govern attachments of muscles, their influence being specific for particular bones and for localized regions upon any one bone. Whether the influence is determined through germinal inheritance or is the result of the recognized interdependence of structures in development, or both, a definite dynamic nature may be attributed to the developing bones. Muscle attachments in the feet described are believed to be the result of operation of such dynamic factors, variations concerned with hyperdactylism being secondarily produced through doubling of the bones. Assuming that each of the two halluces carries a full complement of the dynamic factors governing insertions of individual hallucal muscles upon particular areas of their bones, as is indicated by normal areas of attachment and typical morphology of the bones themselves, it is inferred that each hallux can control attachments of those muscles which are environmentally related to it, rather than to the other hallux. That the two halluces of each foot exerted approximately equal control of those muscles related to their dorsal and plantar surfaces is evidenced by bifurcation of the long extensor and flexor tendons. On the right side, the insertion upon the lateral hallux of a slip from the flexor digitorum brevis suggests the environmental

displacement of this hallux. This accessory slip and a similar one to the medial hallux from the flexor digitorum longus perhaps are the consequence of the unnatural expansion of their flattened embryonic tendon plates, due to increased width of the foot as a whole, with subsequent formation of supernumerary tendons. In the right foot the medial hallux more nearly assumes the nature of a normal hallux, with regard to musculature, and thus is assumed to have been in an environment approaching the normal. Of the four halluces concerned, the lateral hallux of this foot appears to be farthest removed from a hallucal environment while in the left foot the two halluces seem to be complementary with reference to the medial and lateral aspects of the normal hallux.

Since arterial variations occur, not in the courses of main trunks, but in the size, number, and distribution of terminal branches, it is inferred that they are the result of environmental relationships in development rather than of any germinal correlation between hyperdactylism and the differentiation of vessels. Senior describes the formation of dorsal and plantar plexuses within the mesenchyme of the foot, from which are derived all the arteries on the dorsum of the foot, the plantar arch and all the terminal branches on the distal portion of the sole (excepting the trunks of the lateral and medial plantar arteries). The three trunks, medial plantar, dorsalis pedis (resolved within the dorsal plexus), and lateral plantar, establish their permanent connections in the order named. While no emphasis is placed upon the ascendancy of the deep plantar and medial plantar in supplying the region of duplication, the fact is at least suggestive of a permanent dominance of those vessels which first establish their permanent connections in a region characterized by an abnormally large mass of tissue.

There is no involvement in the courses and fundamental relations of the nerve trunks. Thus the medial terminal division of the deep peroneal retains its typical relation and is not influenced by the medial hallux. This relation recalls the insertions of hallucal muscles as they obtain in the left foot. Branching of the medial dorsal cutaneous and medial plantar nerves is

suggestive of the bifurcated extensor and flexor tendons to the two halluces. The complex interrelation between the medial and lateral divisions of the medial proper digital may be the result of retained regionally specific dynamic influences of the normal single hallux. The combined cross-section areas of the two hallucal branches of the medial dorsal cutaneous are approximately twice that of the normal single branch; this relation holds also for the two branches of the medial plantar which supply the halluces. Unfortunately, no counts of the contained nerve fibers could be made, to determine whether the increased volume is due to excess in number of nerve fibers or amount of connective tissue. Even though a correlation between number of spinal ganglion cell bodies and increased area to be supplied does exist, it seems hardly necessary that germinal factors provided the mechanism for correlation. Occurring early, the duplication of the hallucal sensory area might still influence the proliferation of ganglion cells.

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Resumen por el autor, Albert Kuntz.

Un caso de preñez anormal con retención de los fetos muertos en el conejo.

Una coneja preñada exhibía en la cavidad peritoneal dos fetos muertos encapsulados a término y en el útero dos fetos normales vivos de 18 mm. de longitud. Los tejidos de los fetos muertos aparecían necróticos pero bien conservados. Las membranas coriónica y amniótica faltaban, excepto en el área placentaria. Las cápsulas consistían en membranas delgadas de tejido conectivo viable con abundante irrigación sanguínea, si bien su inserción en cualquiera de las estructuras intraabdominales era muy ligera.

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A CASE OF ABDOMINAL PREGNANCY WITH RETENTION OF DEAD FETUSES IN THE RABBIT

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ONE FIGURE

In the routine of laboratory work a female rabbit was found which, when the abdominal cavity was laid open, exhibited two encapsulated dead fetuses in the peritoneal cavity and a pregnant uterus containing two normal living fetuses 18 mm. in length. I am indebted to Dr. M. S. Fleisher for this material.

The literature of obstetrics and gynecology contains the reports of not a few cases of abdominal pregnancy in the human species. In some of these cases a dead fetus was carried in the peritoneal cavity for a relatively long time following the normal period of gestation. Barring infection or accident in such cases, the fetal tissue slowly undergoes absorption. A few cases of abdominal pregnancy in animals have also been reported.

In the majority of the reported cases of abdominal pregnancy the fetal envelope and placenta, in cases examined early, or the capsule containing the dead fetus, in cases examined late, showed extensive and firm attachment to the peritoneum or mesentery. Not uncommonly, one of the ovaries was involved in the attachment. When the present case came into my hands the encapsulated fetuses were lying unattached in the peritoneal cavity. The laboratory assistants who had opened the abdominal cavity and removed the fetuses insisted that they had broken no attachments of the capsules to any intra-abdominal structure. Furthermore, careful inspection of the capsules revealed no areas of attachment.

The encapsulated dead fetuses, the ovaries, the uterus, and the living fetuses contained in it were fixed and preserved in 10 per

cent formalin and subjected to further study. The ovaries proved to be normal in all respects, containing both corpora lutea and corpora albicantia. The fallopian tubes also were normal. The presence of normal living fetuses in the uterus is of little importance except as an indication that the encapsulated fetuses were carried as dead bodies in the abdominal cavity for some time. There is no means at hand of determining how much time elapsed between the successive pregnancies. Encapsulated with each dead fetus was a mass of dead placental tissue. The capsule was closely applied to the fetus and the placental mass and presented the appearance of a thin connective tissue membrane. One of the encapsulated fetuses is illustrated photographically in the accompanying figure (fig. 1).

Upon microscopic examination the fetal tissues were found to be necrotic, but still sufficiently well preserved to admit of reasonably good staining. The skin was intact and well covered with hair. Sections through the capsule and the underlying skin revealed only remnants of amnionic or chorionic tissue. Obviously, these tissues were almost completely absorbed except in the placental area. The capsule consists of a thin connective-tissue membrane containing numerous small blood vessels. It does not blend with the placental mass, but is continuous over the surface of the latter and is of the same character in this area as in areas in which it lies in contact with the fetal integument. The capsular tissue was perfectly fixed and reacted to the stain like freshly killed connective tissue. It does not present the histological appearance of the mesodermal portions of the fetal membranes, but rather that of viable connective tissue. Therefore, the capsule is not of embryonic but of maternal origin. Inasmuch as the capsule consisted of living connective tissue with an abundant vascular supply, we must conclude that it was attached to the peritoneum or mesentery at some point, although the attachment was so slight that neither was it observed during the postmortem examination, nor was the area involved detected on later inspection of the capsule.

As indicated above, the ovaries and fallopian tubes were normal in all respects. No scars or other evidence of tubal or ovarian

pregnancy which might have ruptured or discharged into the peritoneal cavity could be detected. The possibility of primary abdominal pregnancy cannot be precluded. However, the absence of evidence of some other type of ectopic pregnancy in this case does not warrant the conclusion that the ova were extruded into the peritoneal cavity before they had secured implantation sites elsewhere. According to the modern view as

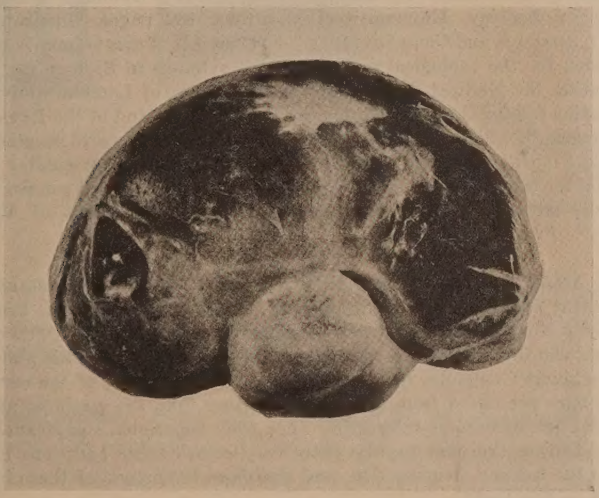

Fig. 1 Photographic illustration of encapsulated dead fetus

set forth by Kelly,[1] Williams,[2] and others, the theoretical possibility of primary abdominal pregnancy is admitted, but conclusive evidence that it actually occurs is not forthcoming. Conclusive proof of primary abdominal pregnancy in any case in which gestation is well advanced is obviously impossible. The facts in the present case are not incompatible with the theory that the ova were discharged into the peritoneal cavity after gestation was initiated.

[1] Kelly. Amer. Textbook of Obstetrics. 1895.
[2] Williams. Obstetrics. 1912.

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(Continued from first page)

AN INTRODUCTION TO ZOOLOGY by C. H. O'Donohue, D.Sc., F.Z.S., Professor of Zoology, University of Manitoba, 502 pages, illustrated. New York: D. Appleton and Company, 1921. "The object of this volume is to provide a text-book for the zoological position of the syllabus in Biology for the First Examination for Medical Degrees of the University of London, and the First Examination for the Conjoint Examining Board in England of the Royal College of Physicians of London and the Royal College of Surgeons of England. It is hoped that it will also prove useful to students preparing for similar examinations, and for those who are taking classes, like the pre-medical courses in American Universities, requiring a knowledge more particularly of Vertebrate Zoology." *From the Preface.*

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